Site Characterization of the Highest-Priority Geologic Formations for CO_2 Storage in WY

Ronald C. Surdam
State Geologist

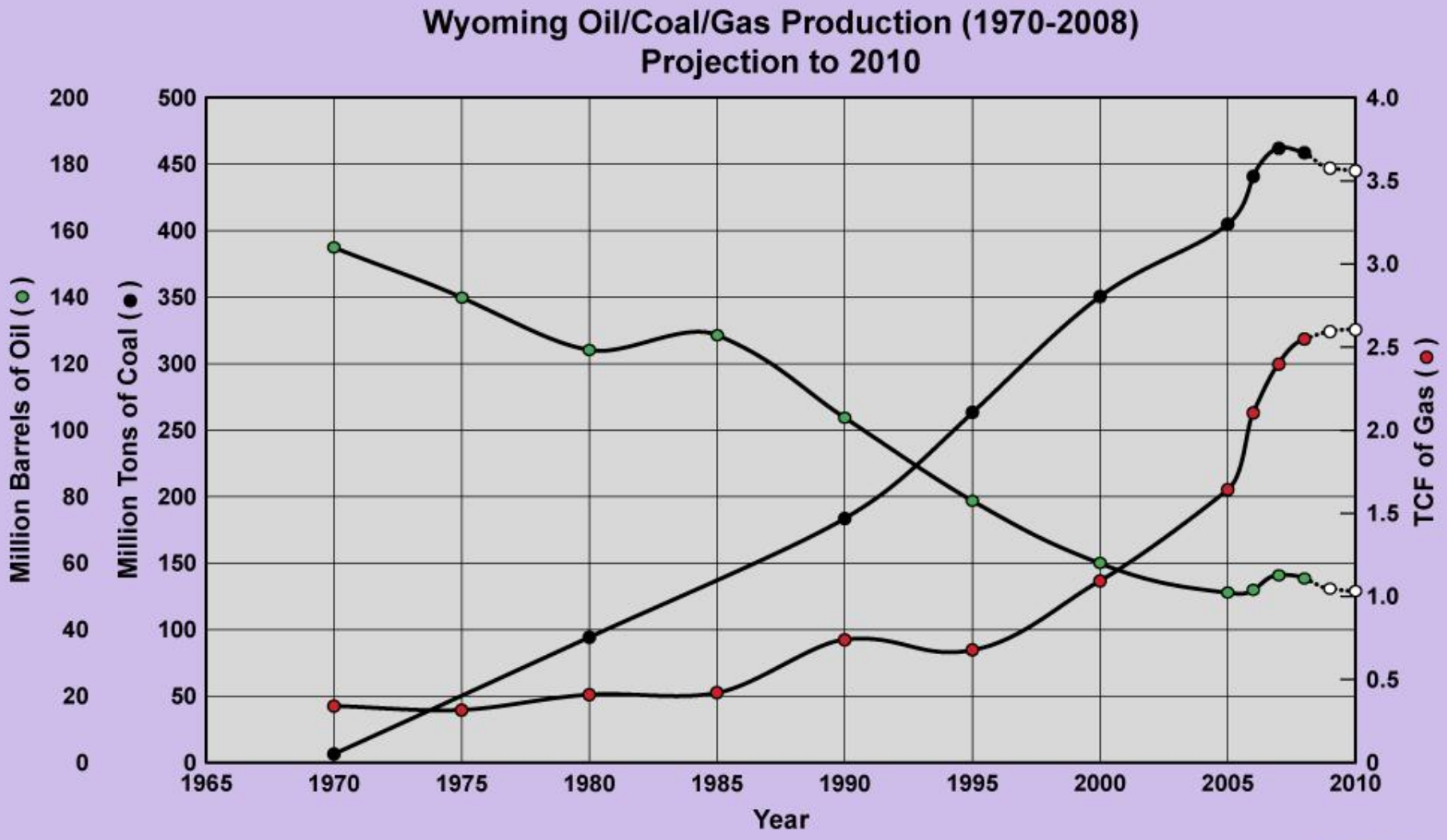
SER

University of Wyoming

State of Wyoming Geological Survey 1933

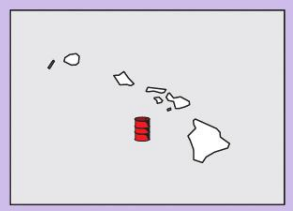
Overview

- Project Background
- WY-CUSP Philosophy & Goals
- Project Objectives
- Project Structure & Cost
- Future Directions



Modified from Surdam, R.C., 2008, Wyoming energy development in the context of the global economy: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 6, 38 p.

Net Domestic Energy
Export vs. Import



= 4 quadrillion Btu's from fossil fuel

Surdam, R.C., 2008, Wyoming energy development in the context of the global economy: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 6, 38 p.

STATE OF WYOMING GEOLOGICAL SURVEY 1933

U.S. Energy Imports
2006

Rank	Country or State of Origin	Crude Oil Production Million Bbl/year	Crude Oil Quadrillion Btu	Natural Gas Production Trillion Cubic ft/year	Natural Gas Quadrillion Btu	Coal Production million tons/year	Coal Quadrillion Btu	Total Quadrillion Btu
1	Wyoming	52.93	0.28	1.75	1.77	446.74	7.96	10.01
2	Canada	648.97	3.41	3.59	3.63	1.49	0.04	7.08
3	West Virginia	1.83	0.01	0.22	0.22	152.37	3.91	4.14
4	Mexico	575.61	3.02	0.01	0.01	0.00	0.00	3.04
5	Saudi Arabia	519.40	2.73	0.00	0.00	0.00	0.00	2.73
6	Venezuela	416.83	2.19	0.00	0.00	3.07	0.08	2.27
7	Nigeria	378.51	1.99	0.06	0.06	0.00	0.00	2.05
8	Alaska	270.47	1.42	0.42	0.43	0.00	0.00	1.85
9	Iraq	201.85	1.06	0.00	0.00	0.00	0.00	1.06
10	Angola	187.25	0.98	0.00	0.00	0.00	0.00	0.98
	Total	3,253.61	17.08	6.05	6.12	603.67	11.99	35.19

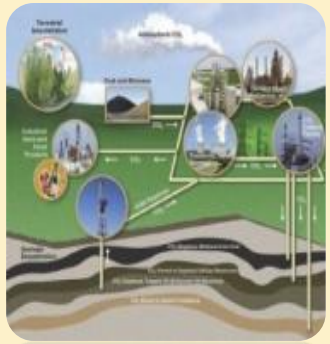
Note: Total may not equal sum of components because of independent rounding.
Coal imports include coal to Puerto Rico and the Virgin Islands.

Source: Bureau of the Census, U.S. Department of Commerce, *Monthly Report IM 145.*
EIA, U.S. Natural Gas Imports by Country
EIA, U.S. Crude oil Net Imports by Country
EIA, Gross Heat Content of Coal Production, Most Recent Annual Estimates, 1980-2006

STATE OF WYOMING GEOLOGICAL SURVEY 1933

Background - Wyoming CO_2 Emissions

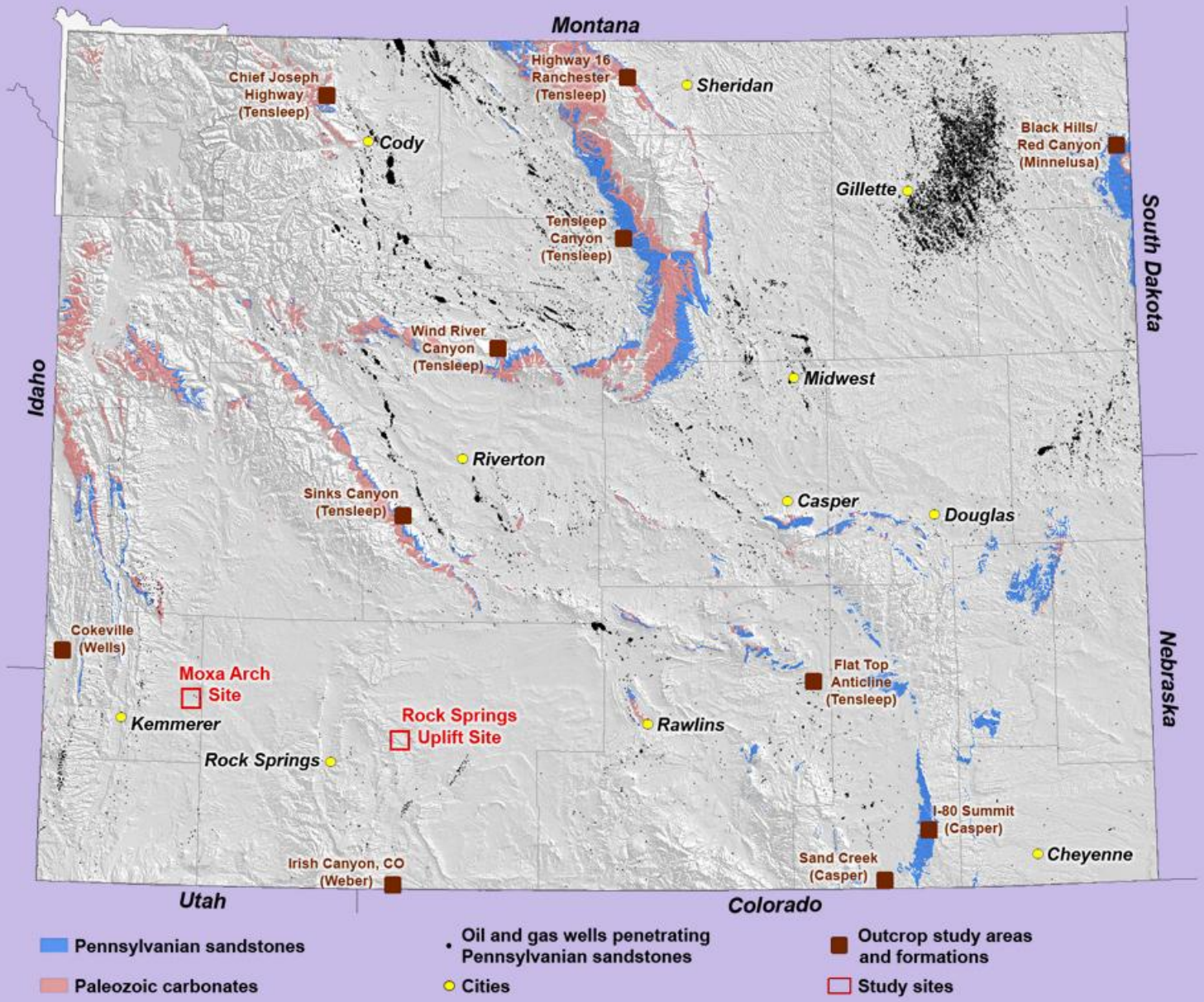
- Wyoming coal-fired power plants currently produce >42 million tons CO_2/yr
- To meet “clean coal” standards, Wyoming must capture and store 18.5 million tons CO_2/yr



SER

UNIVERSITY OF WYOMING

STATE OF WYOMING GEOLOGICAL SURVEY 1933



Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

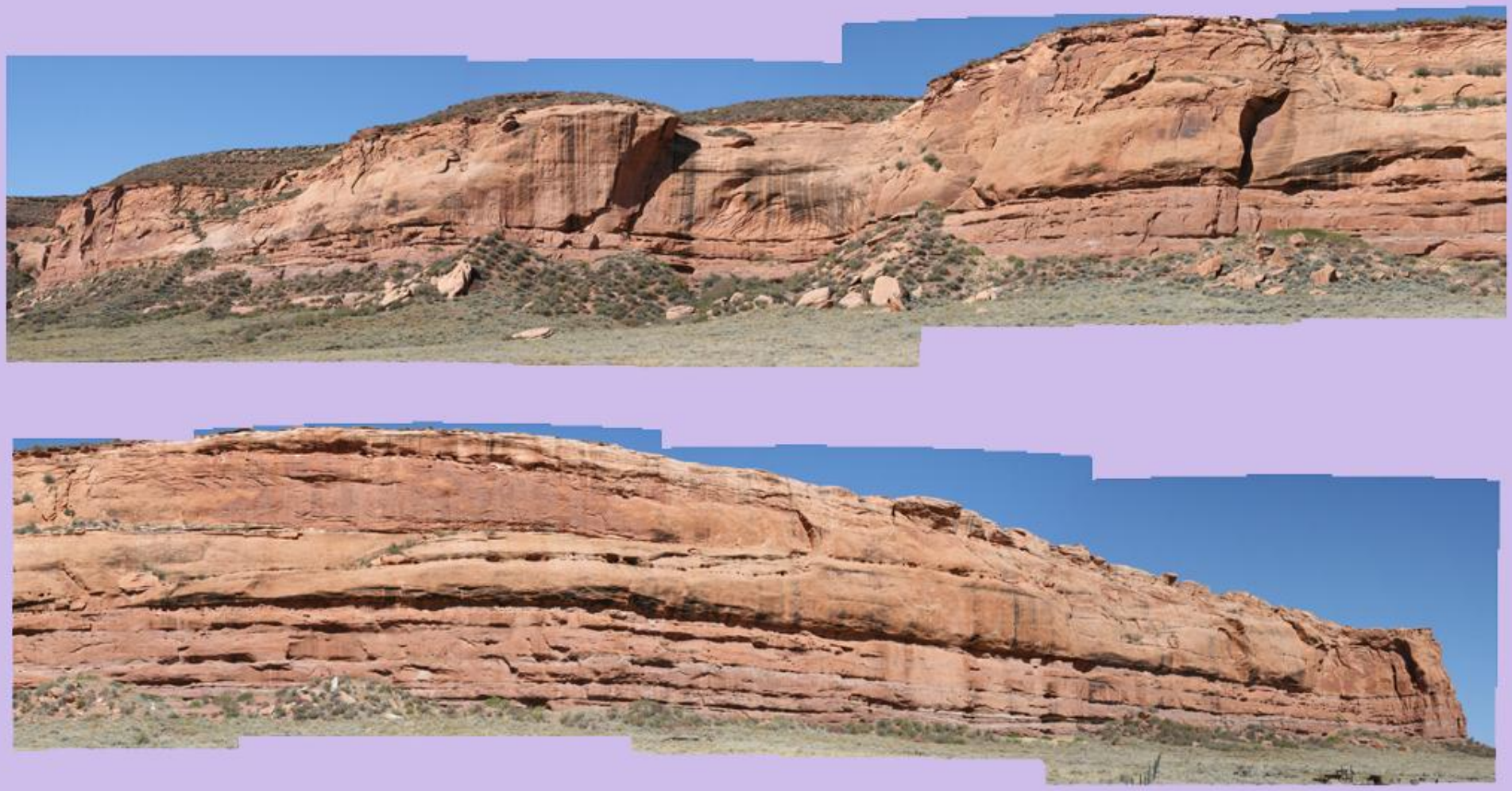
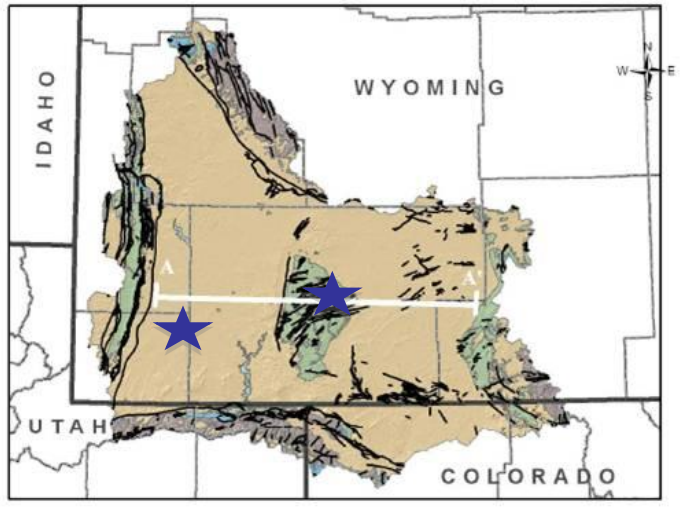


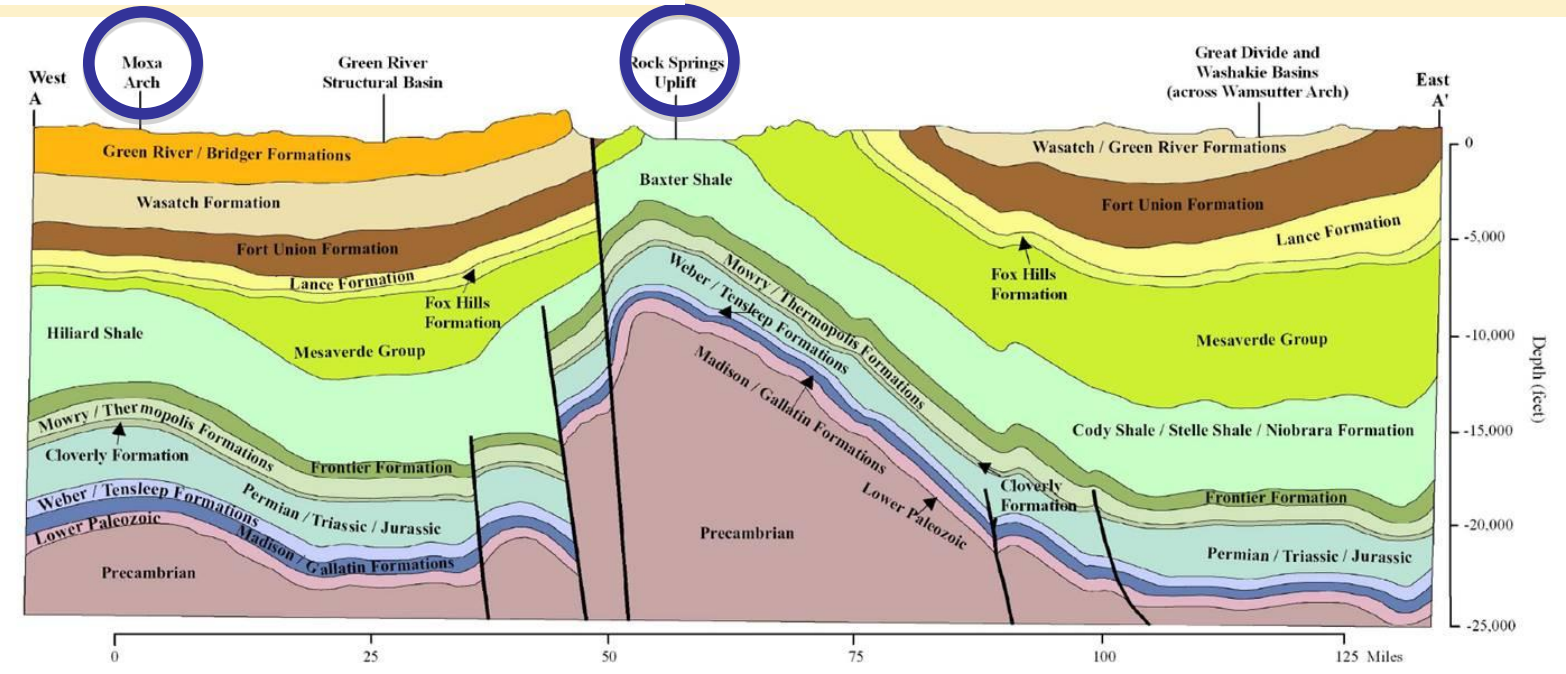
Photo by Z. Jiao, WSGS.

Photo by Meg Ewald, WSGS.

Background – Past Research



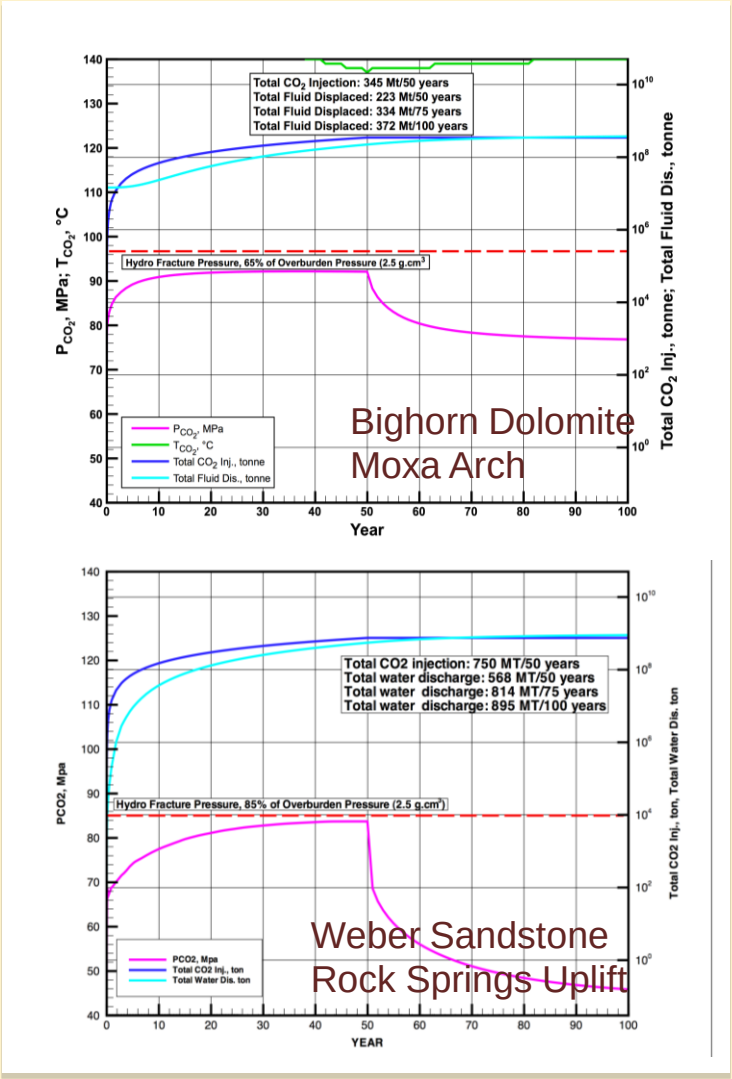
WSGS, UW, state, and DOE-funded research identified two high-capacity sites in southwest Wyoming:
Rock Springs Uplift & Moxa Arch



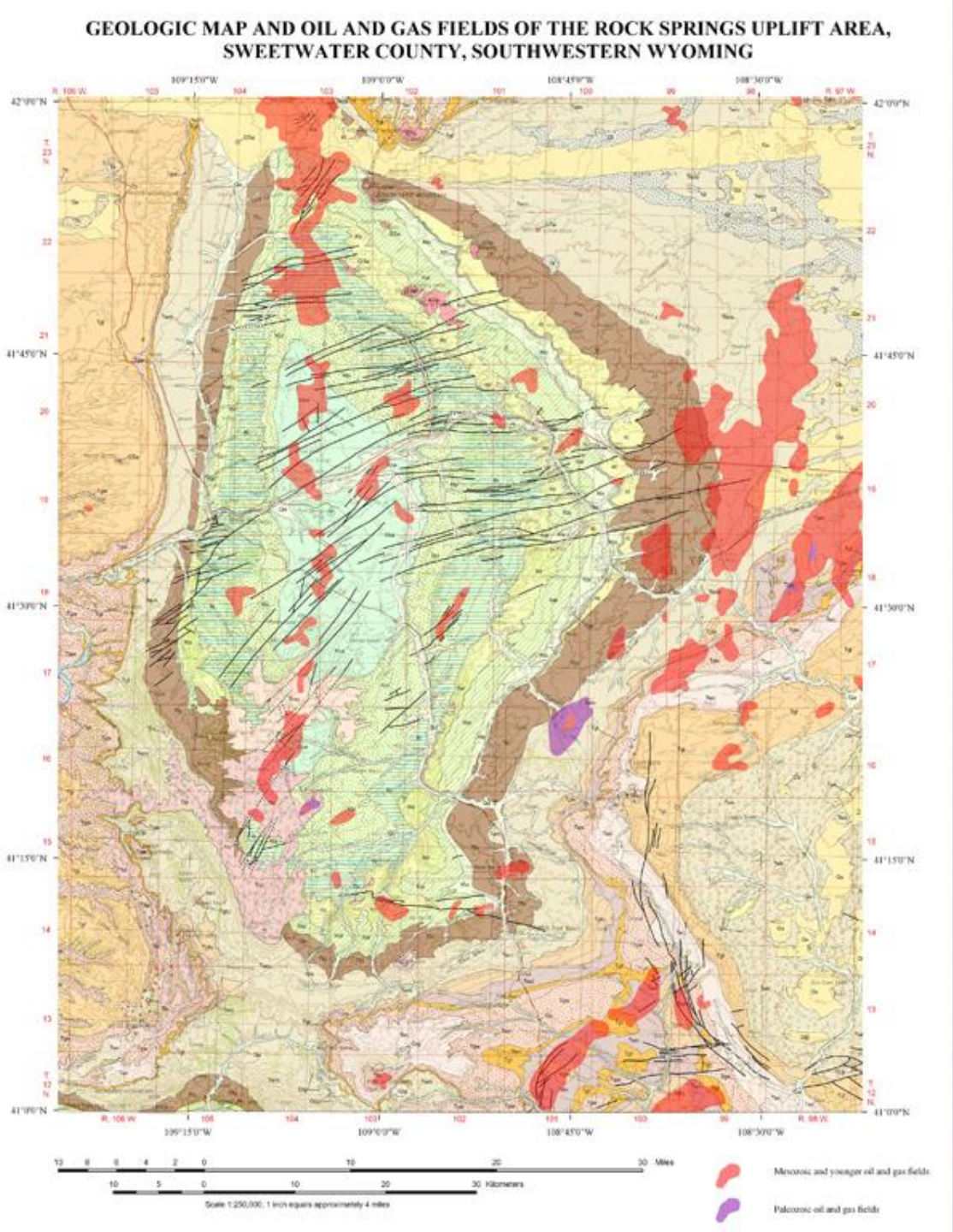
Background – Past Research

UW and WSGS researchers determined that

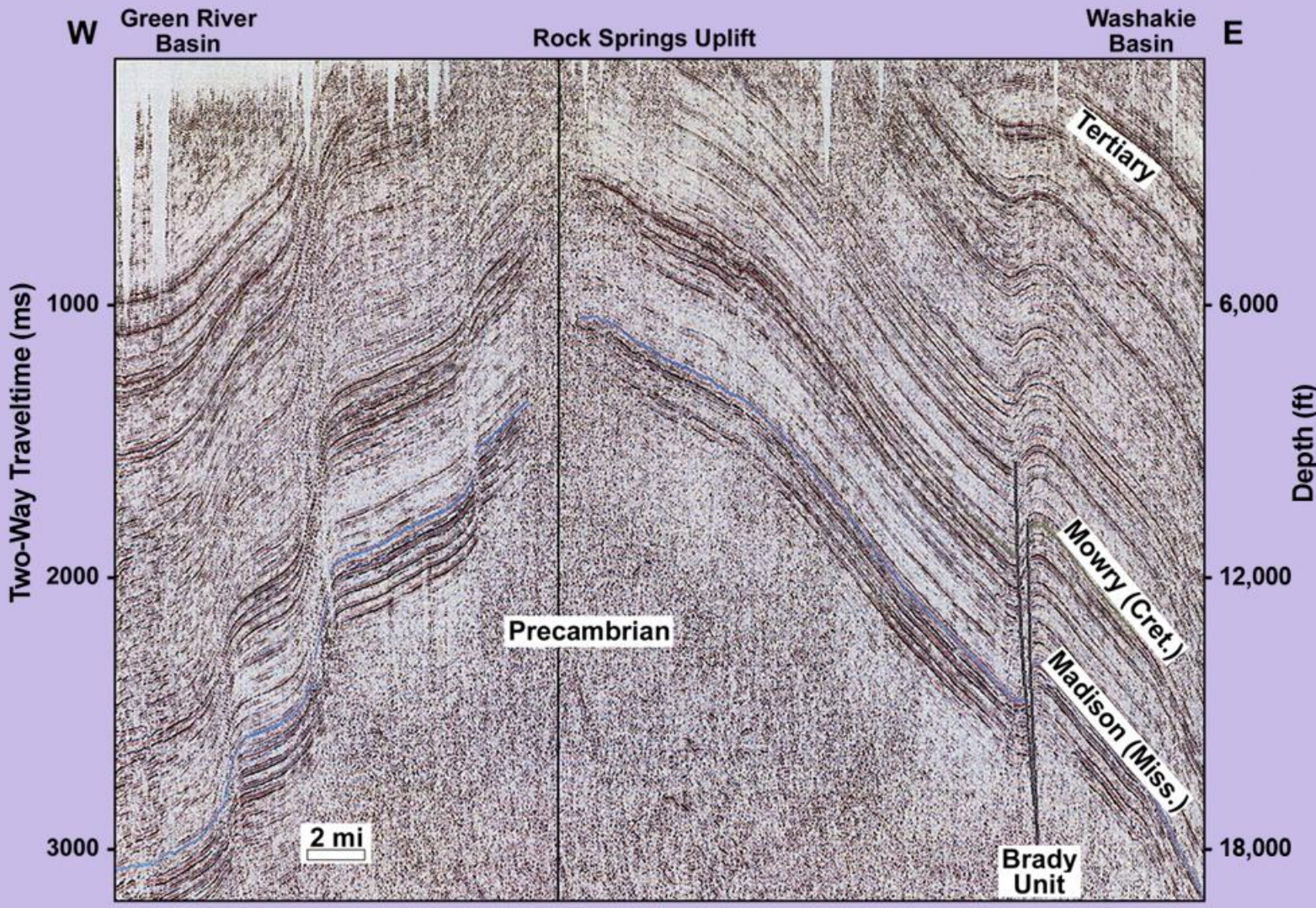
- Bighorn Dolomite on Moxa Arch can accept 7 million tons CO_2/yr for 50 years
- Tensleep/Weber sandstone on Rock Springs Uplift can accept 15 million tons CO_2/yr for 50 years
- Madison limestone has even larger capacity
- Moxa Arch and Rock Springs Uplift can hold >40 billion tons CO_2→***700+ years of current WY CO_2 emissions***



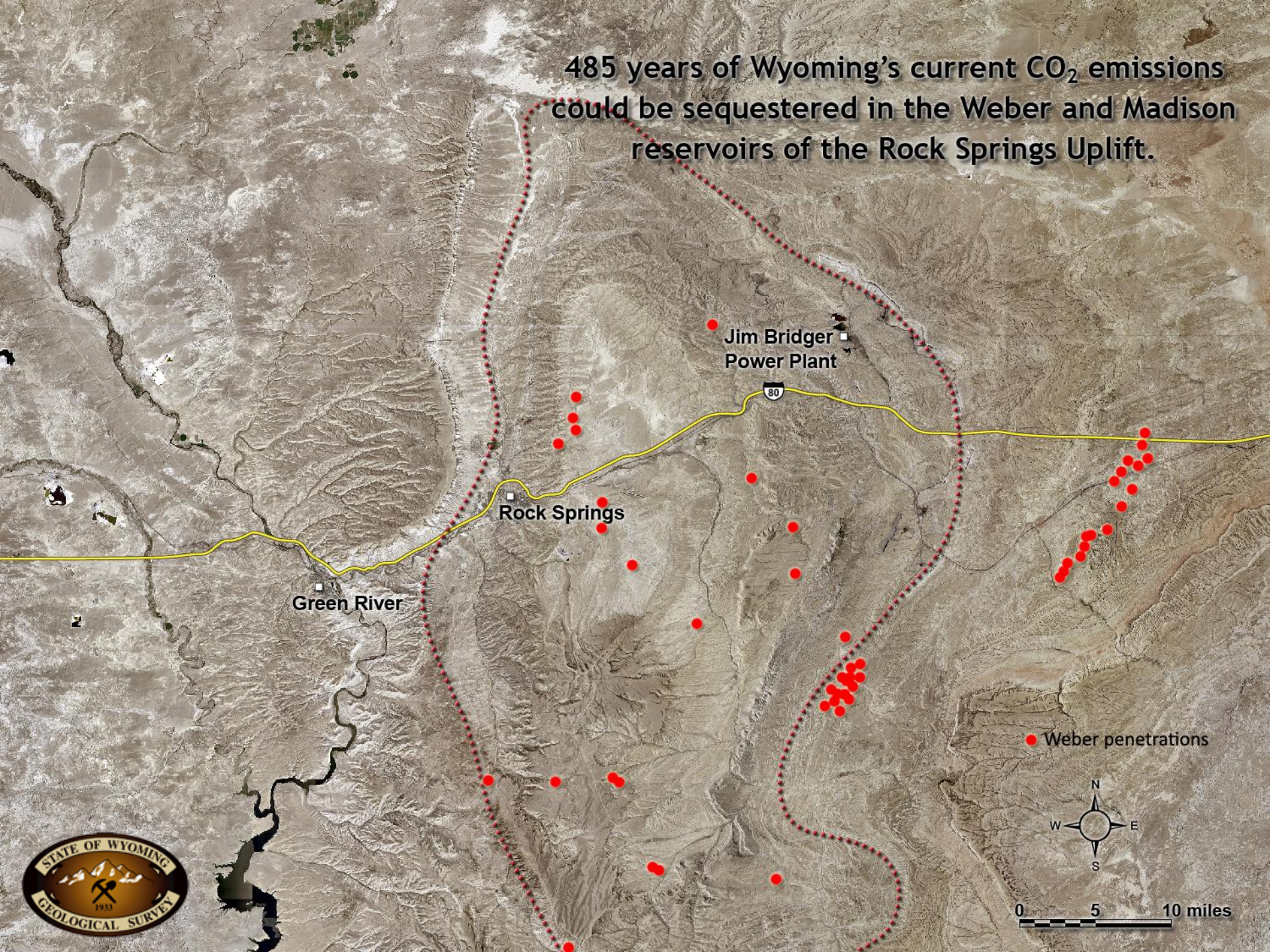
Surdam, R.C., Jiao, Z. Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.



Surdam, R.C. & Jiao, Z., 2007, The Rock Springs Uplift: An outstanding geological CO_2 sequestration site in southwest Wyoming: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 2, 31 p.

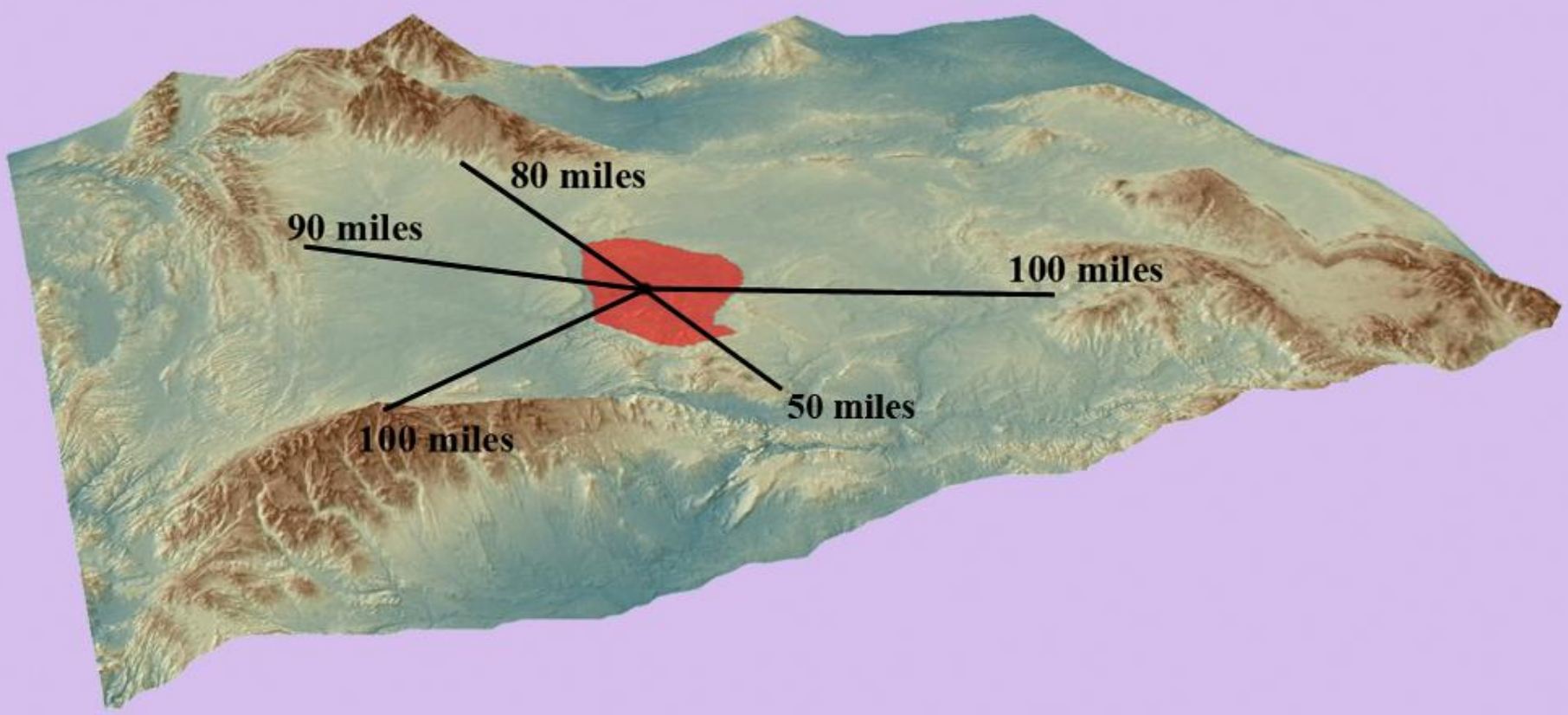


Surdam, R.C. & Jiao, Z., 2007, The Rock Springs Uplift: An outstanding geological CO_2 sequestration site in southwest Wyoming: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 2, 31 p.

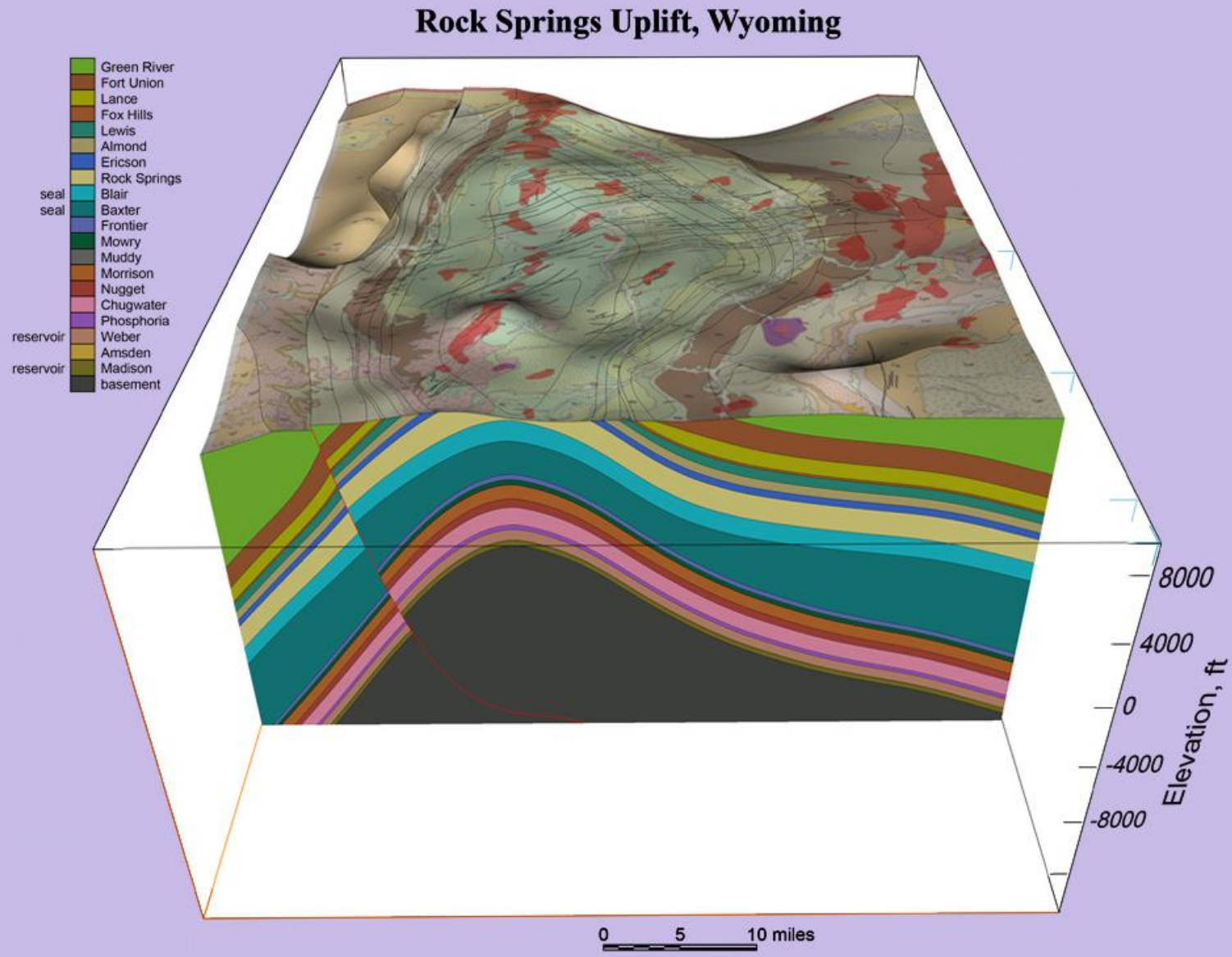

485 years of Wyoming's current CO_2 emissions could be sequestered in the Weber and Madison reservoirs of the Rock Springs Uplift.
Jim Bridger Power Plant
80
Rock Springs
Green River
Weber penetrations
N
W
E
S
0
5
10 miles
STATE OF WYOMING
GEOLOGICAL SURVEY
1933

Rock Springs Uplift: an outstanding geological CO_2 sequestration site in southwestern Wyoming

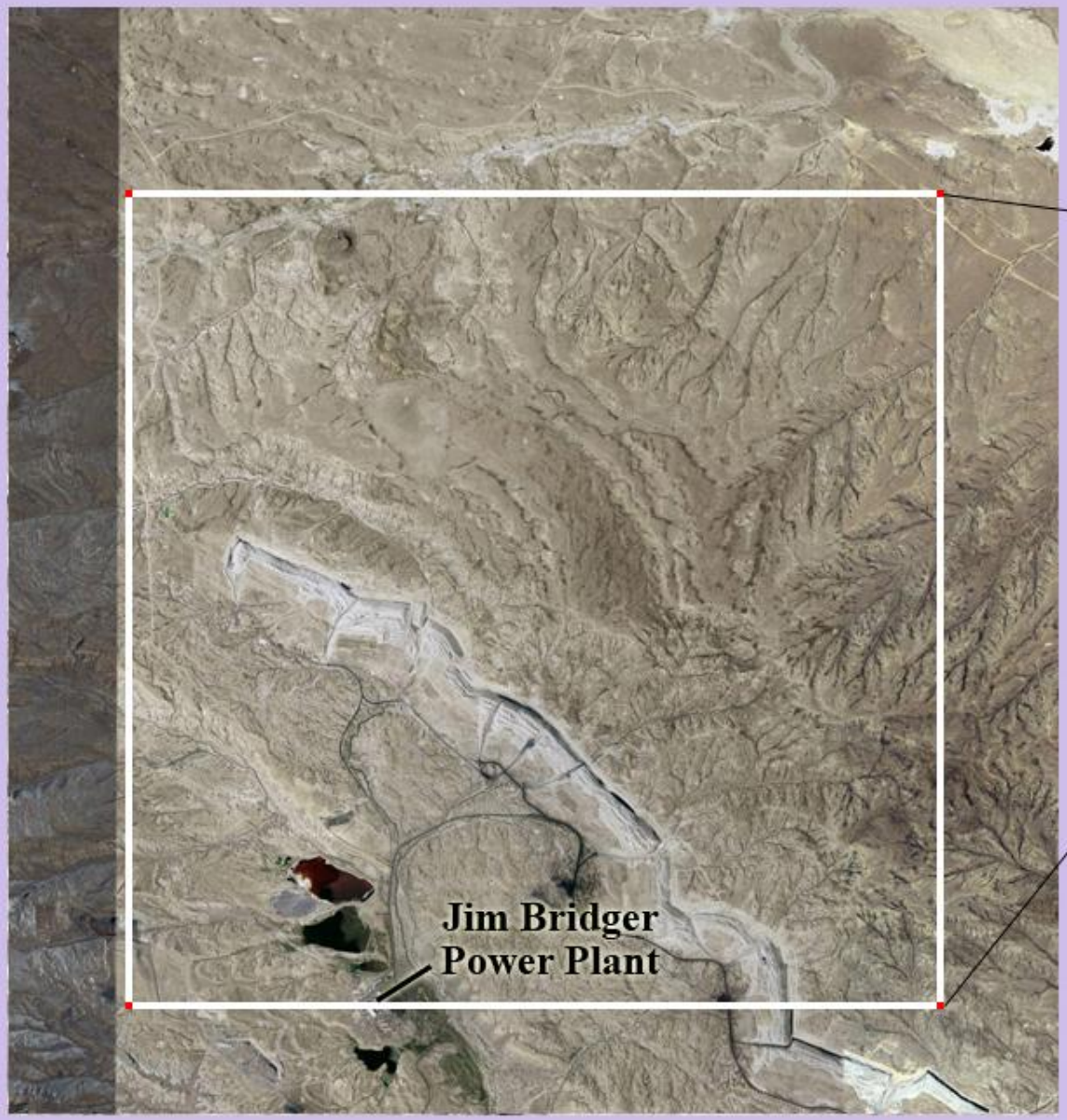
- **Thick saline aquifer sequence overlain by thick sealing lithologies.**
- **Doubly-plunging anticline characterized by more than 10,000 ft of closed structural relief.**
- **Huge area (50 x 35 mile).**
- **Required reservoir conditions; including, but not limited to fluid chemistry, porosity (pore space), fluid-flow characteristics, temperature and pressure (i.e., regional burial history).**

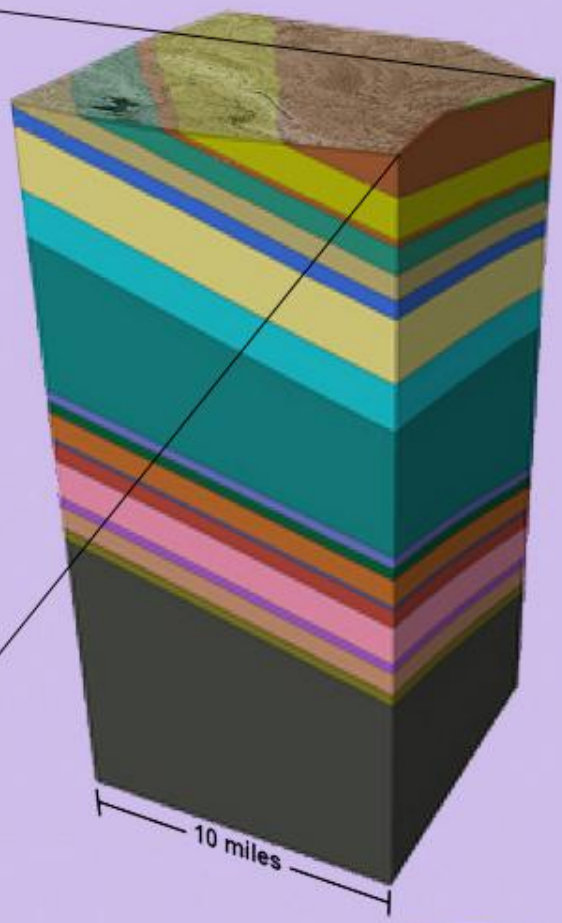


Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.



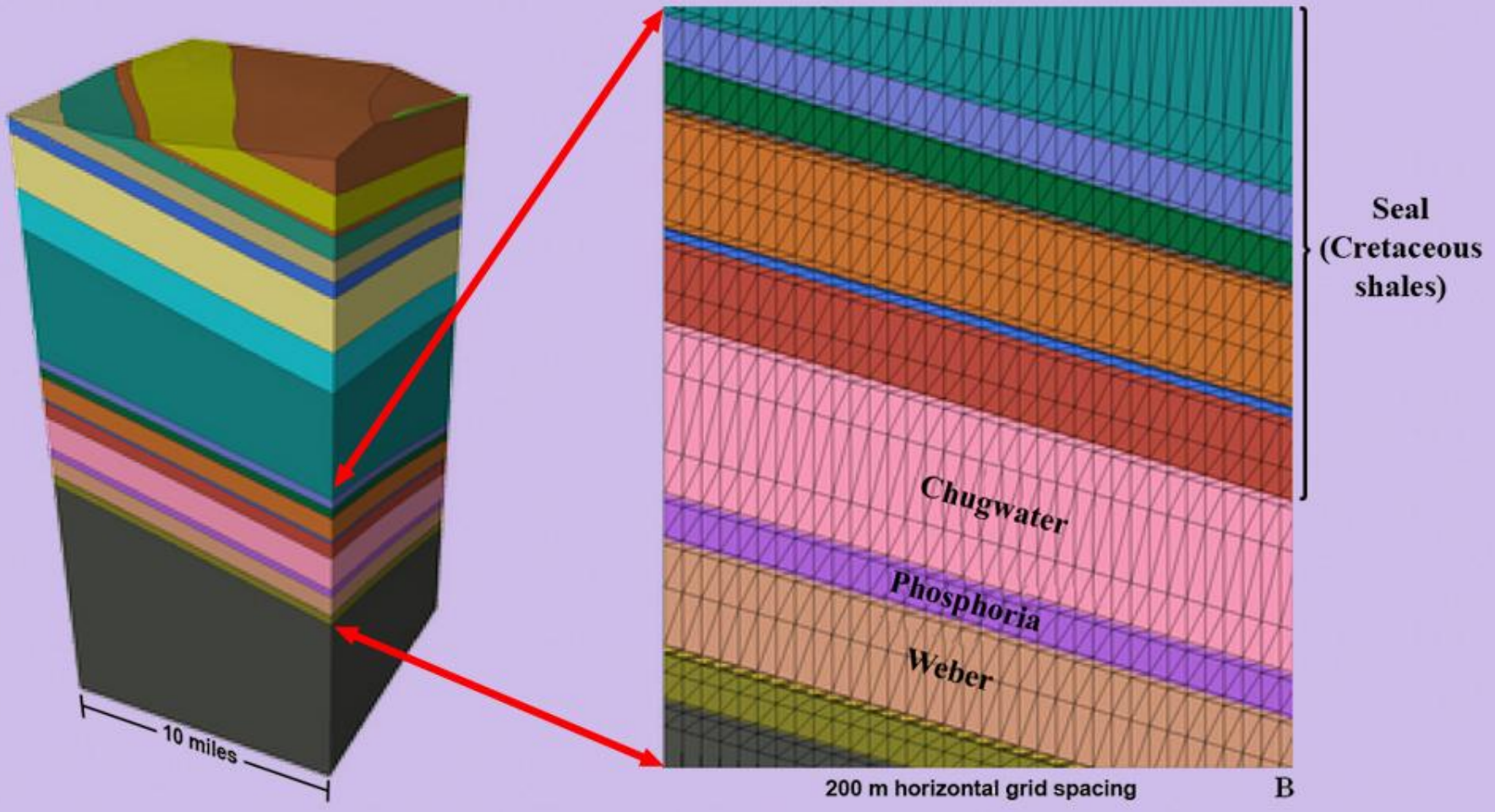
Surdam, R.C. & Jiao, Z., 2007, The Rock Springs Uplift: An outstanding geological CO_2 sequestration site in southwest Wyoming: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 2, 31 p.

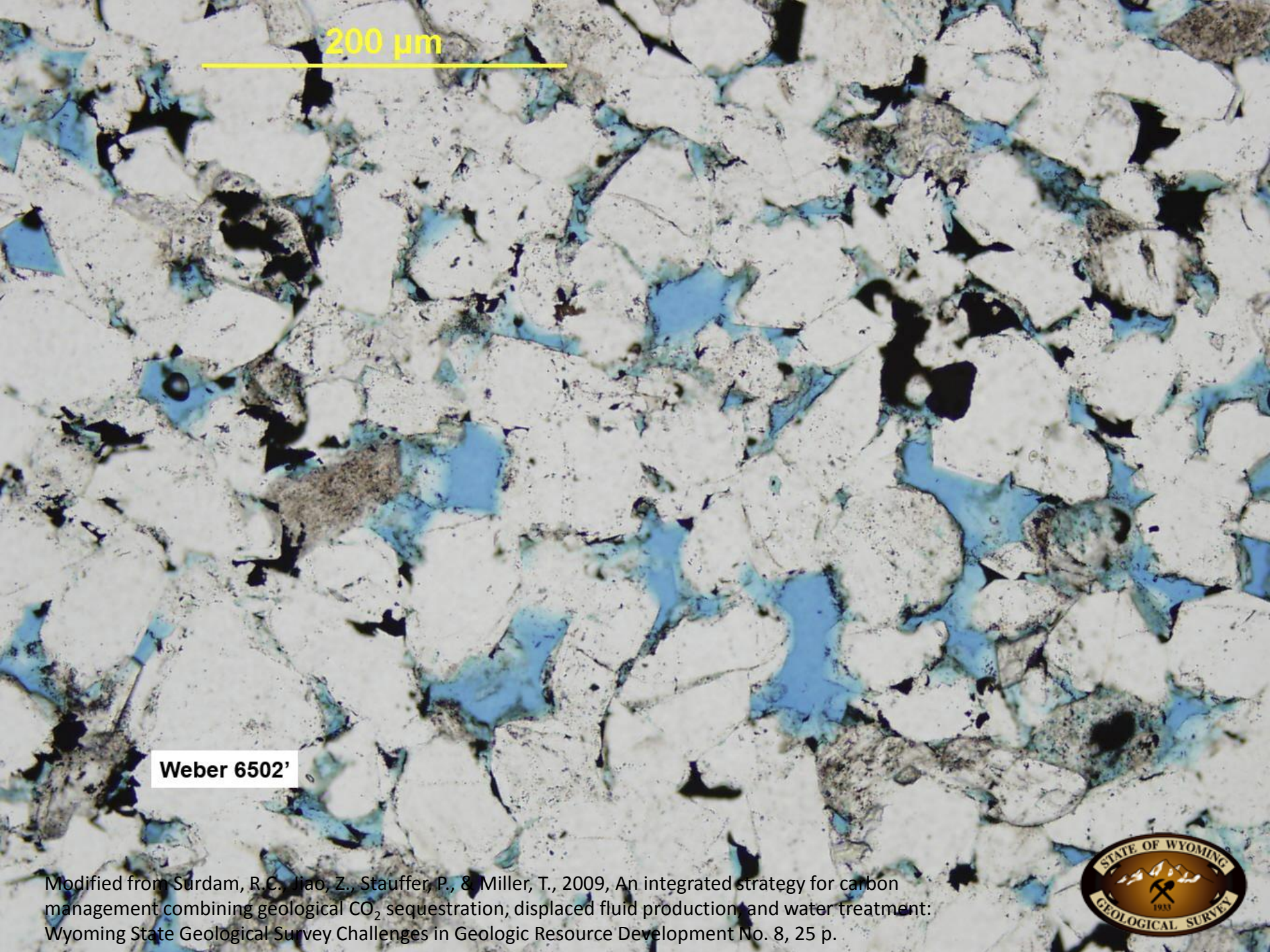




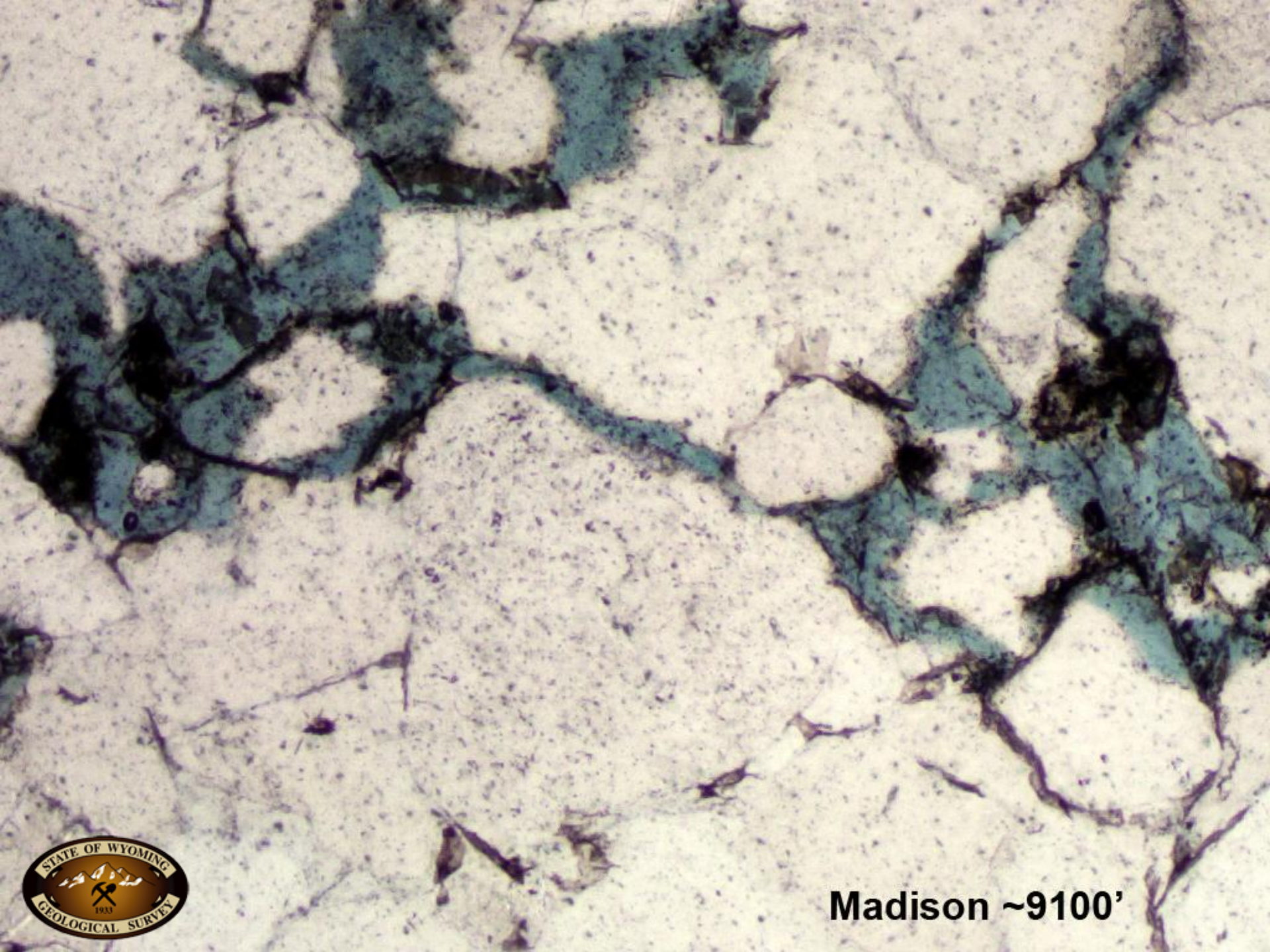
Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

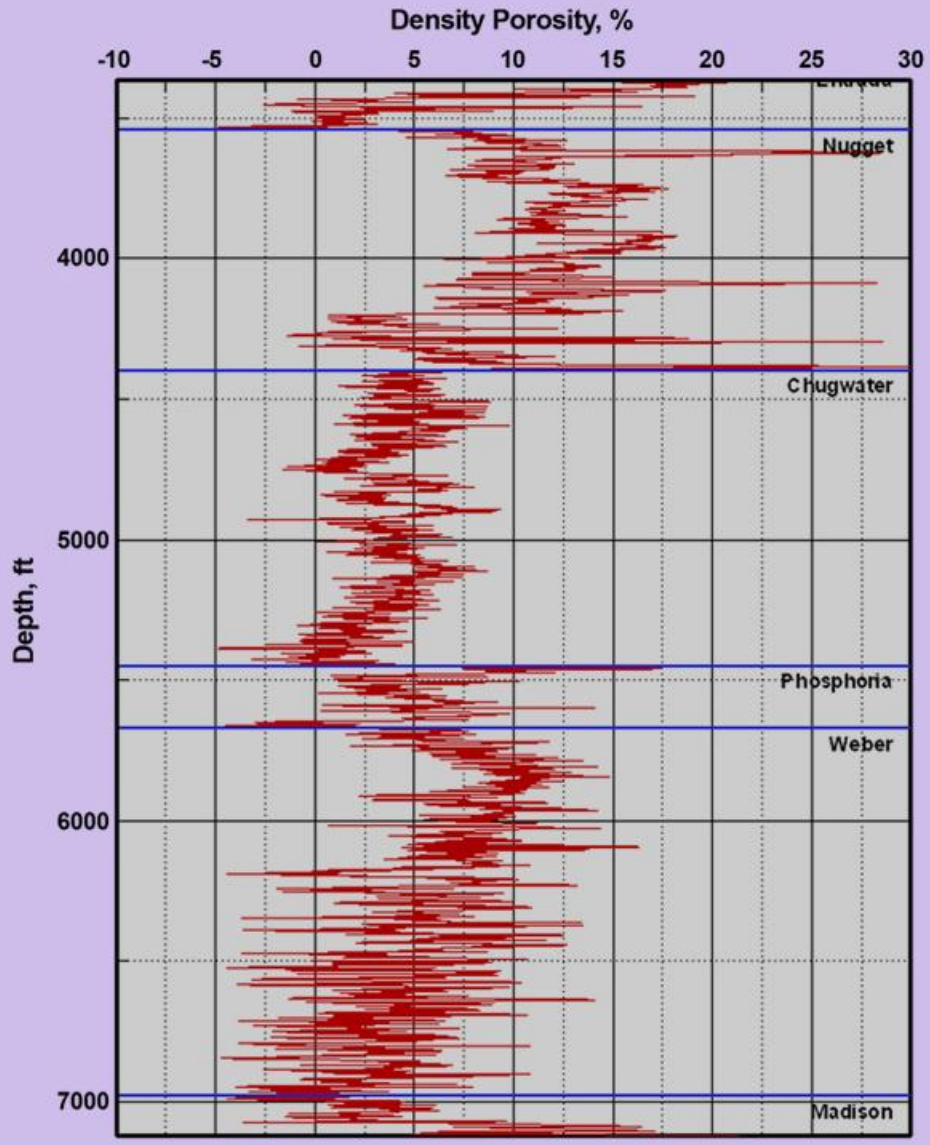
Jim Bridger Power Plant, photo by Meg Ewald, WSGS.


10 miles
Seal
(Cretaceous
shales)
Chugwater
Phosphoria
Weber
200 m horizontal grid spacing
B

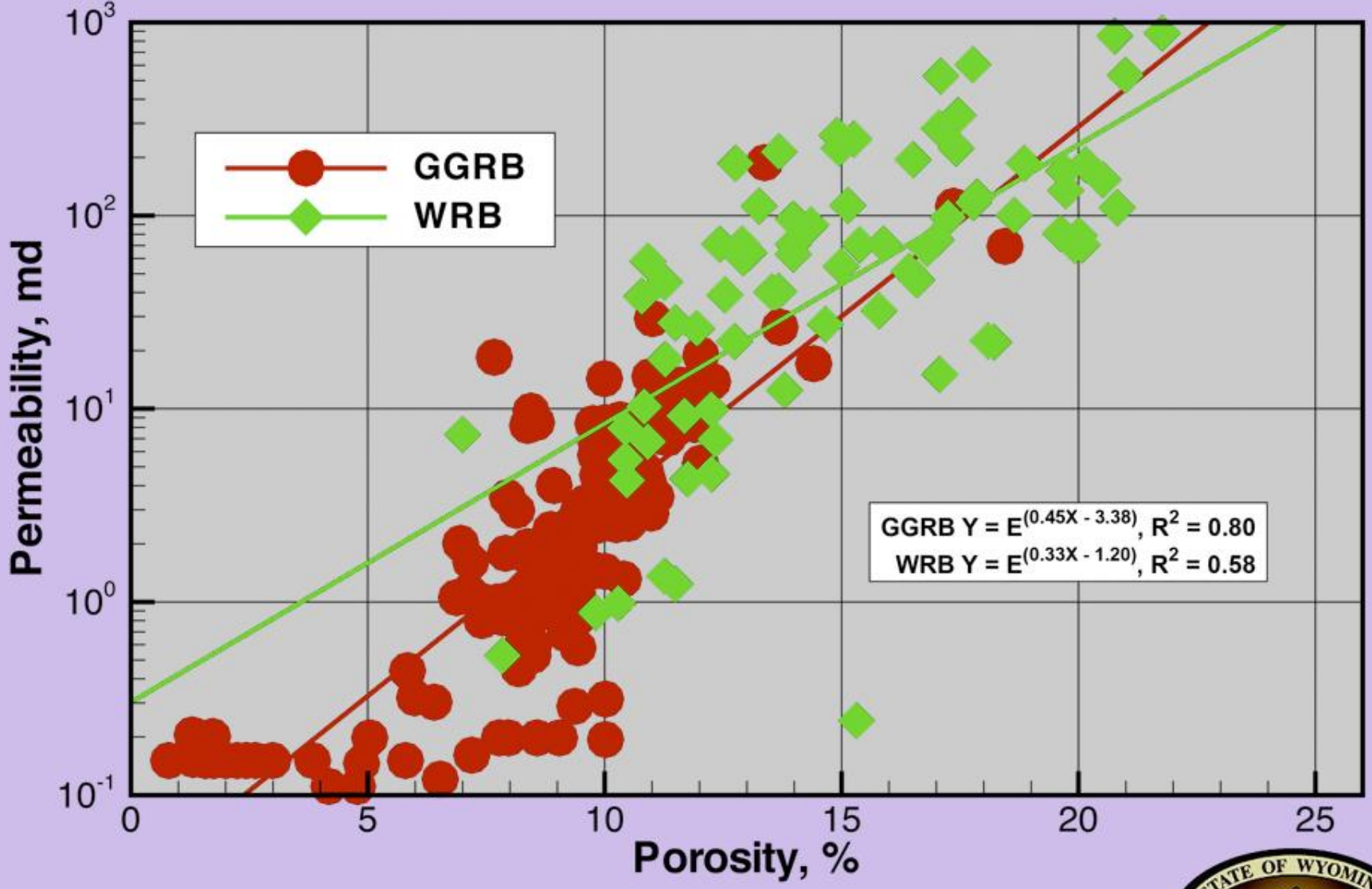


Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.


Madison ~9100’



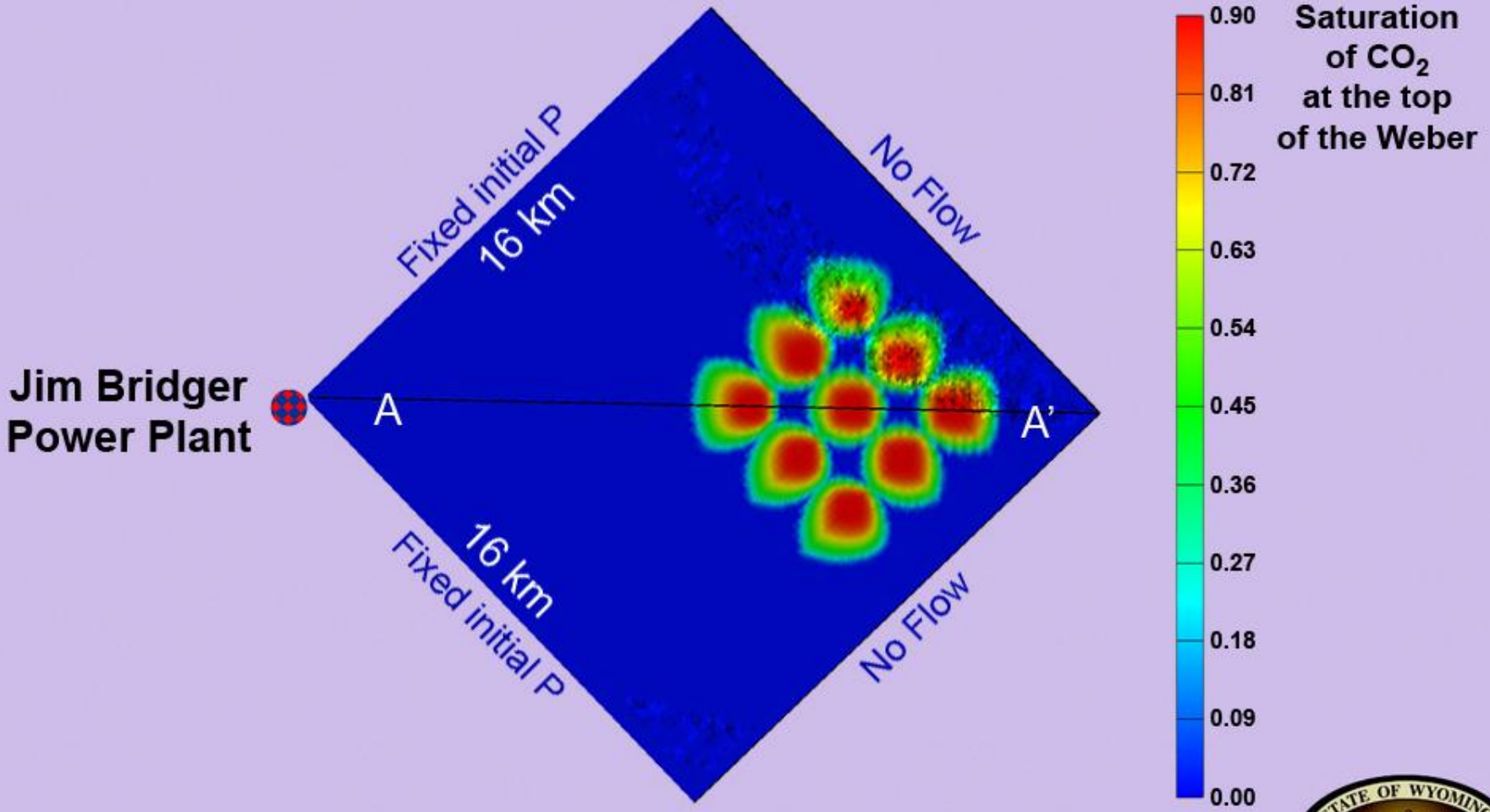
Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.



Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

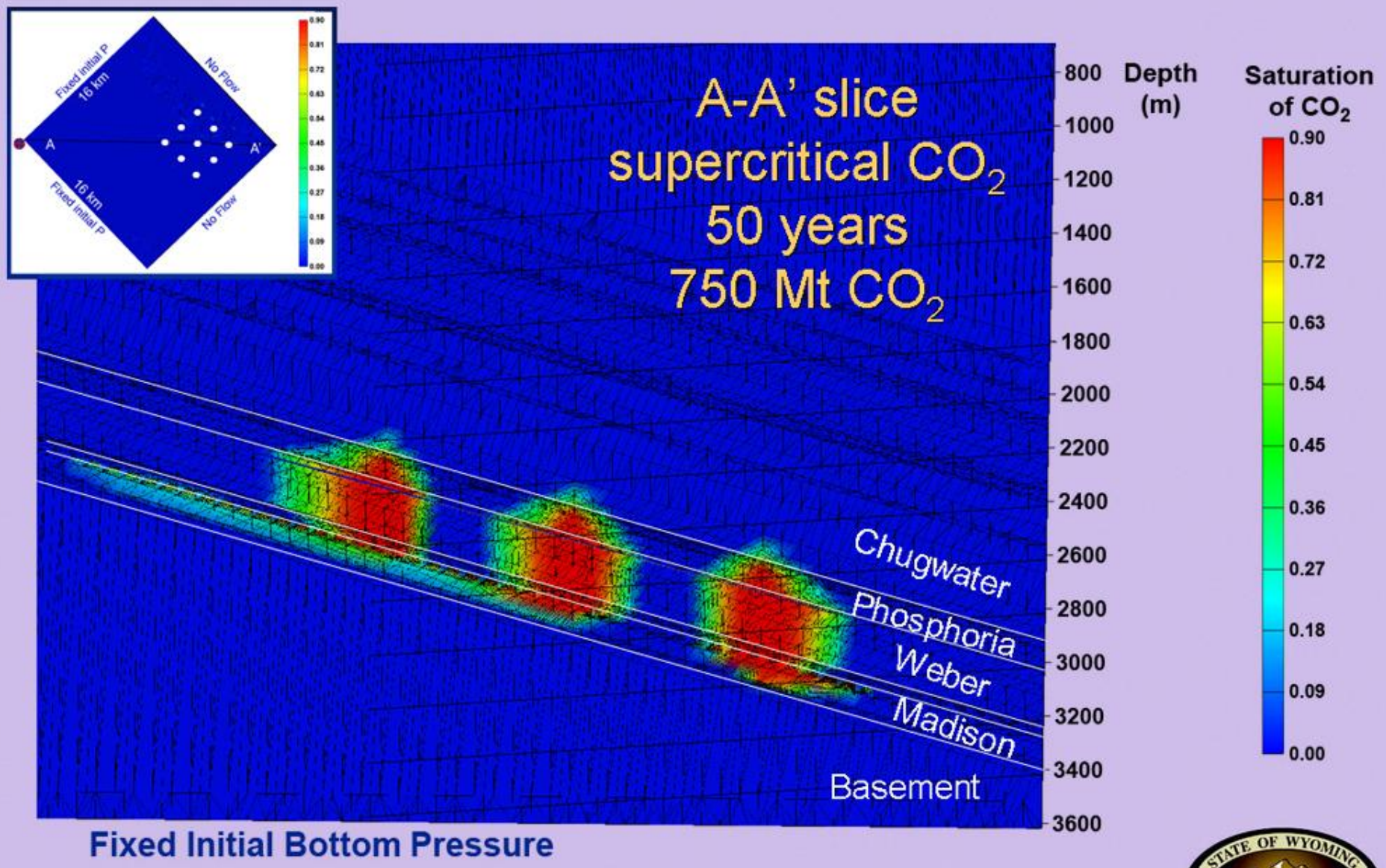
CO_2 Injection Simulation Results from FEHM for the Weber Sandstone, Rock Springs Uplift

Nine point injector example



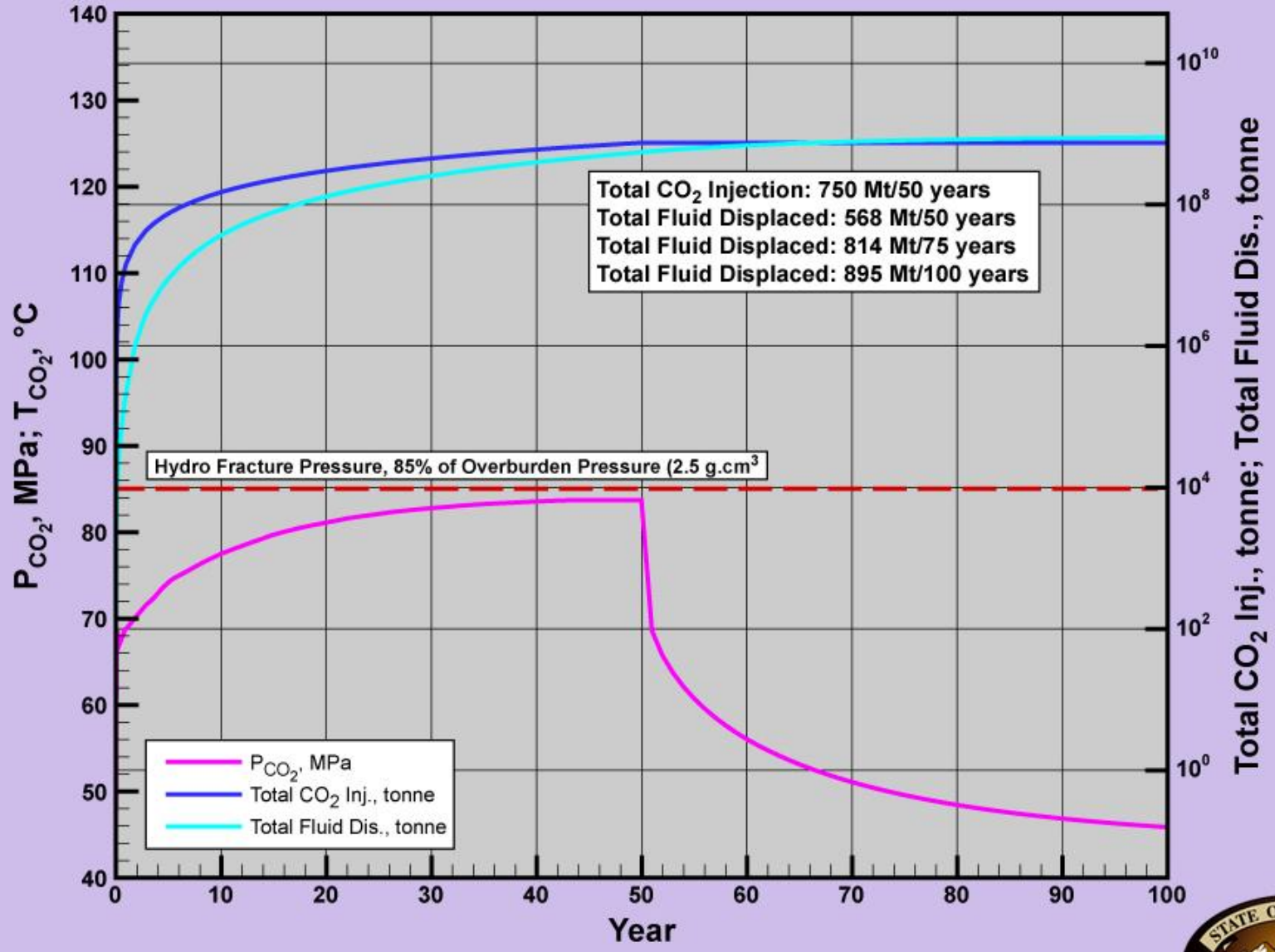
Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

CO_2 Injection Simulation Results from FEHM for the Weber Sandstone, Rock Springs Uplift



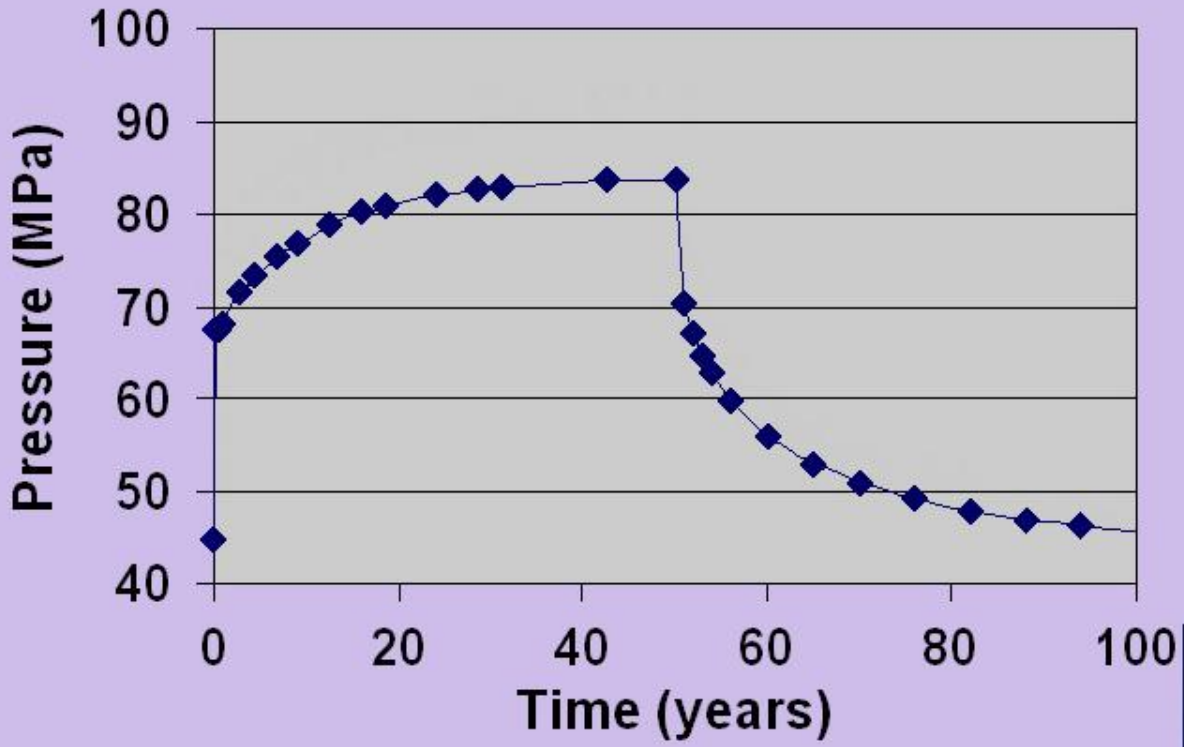
Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

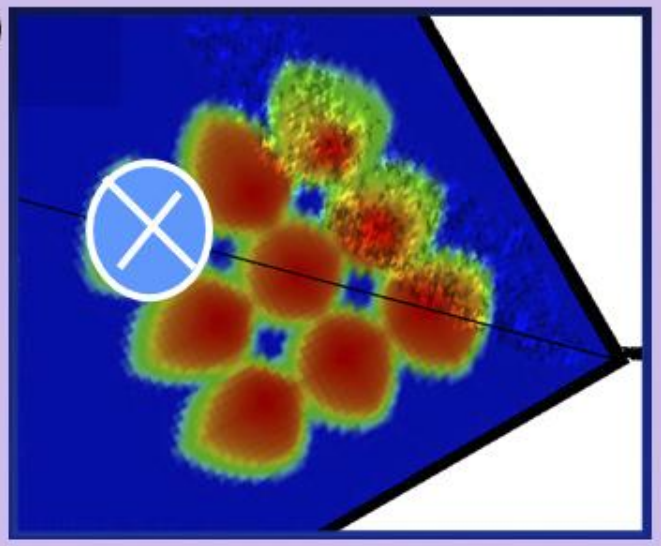
CO_2 Injection Simulation Results from FEHM for the Weber Sandstone, Rock Springs Uplift
Injection Interval 700 ft, Porosity 10%, Relative Permeability 1 md,
Injection Rate 8.8 kg/s, 15 Mt/year, 9 Injection Wells



Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

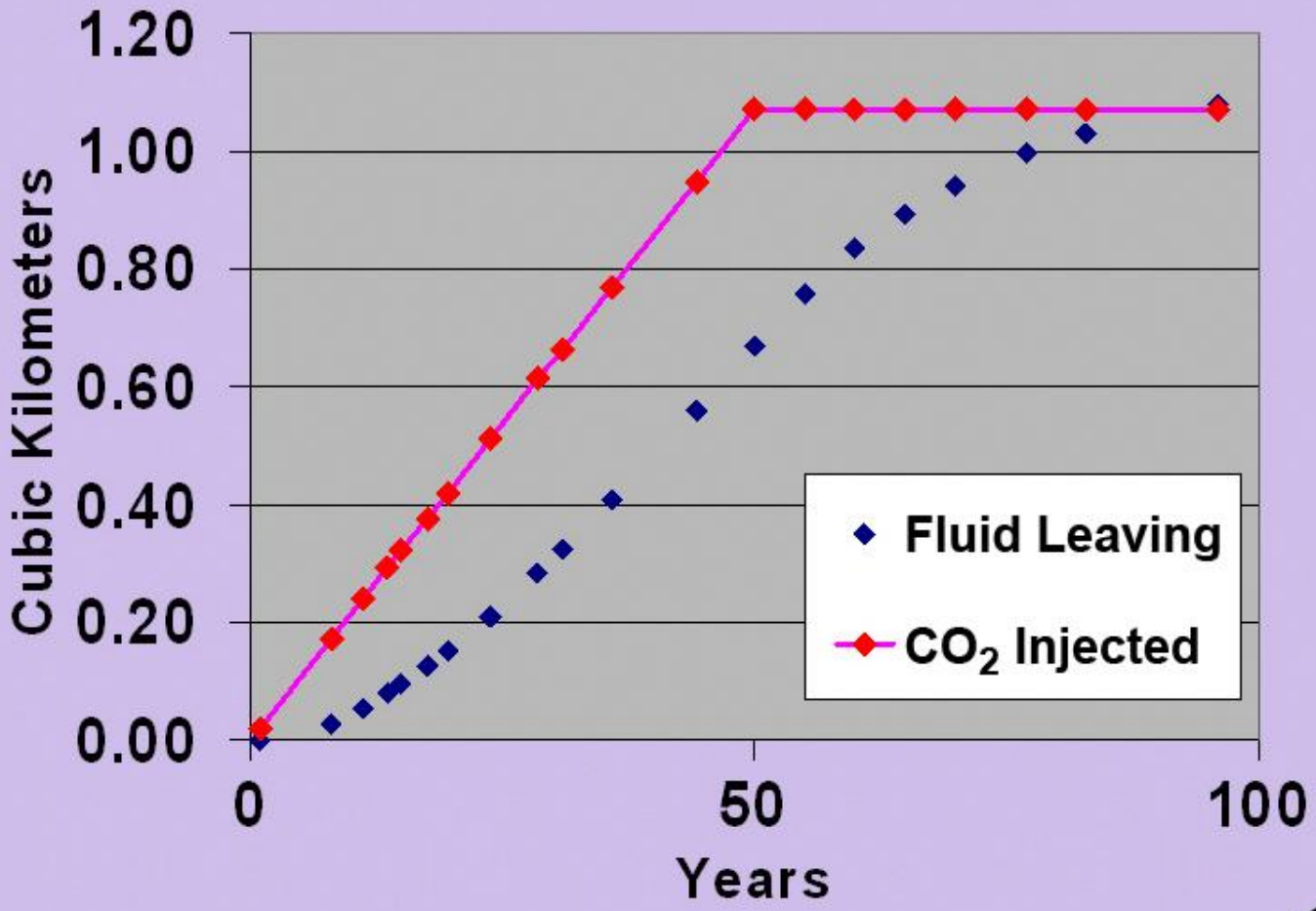
Pressure Evolution





Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

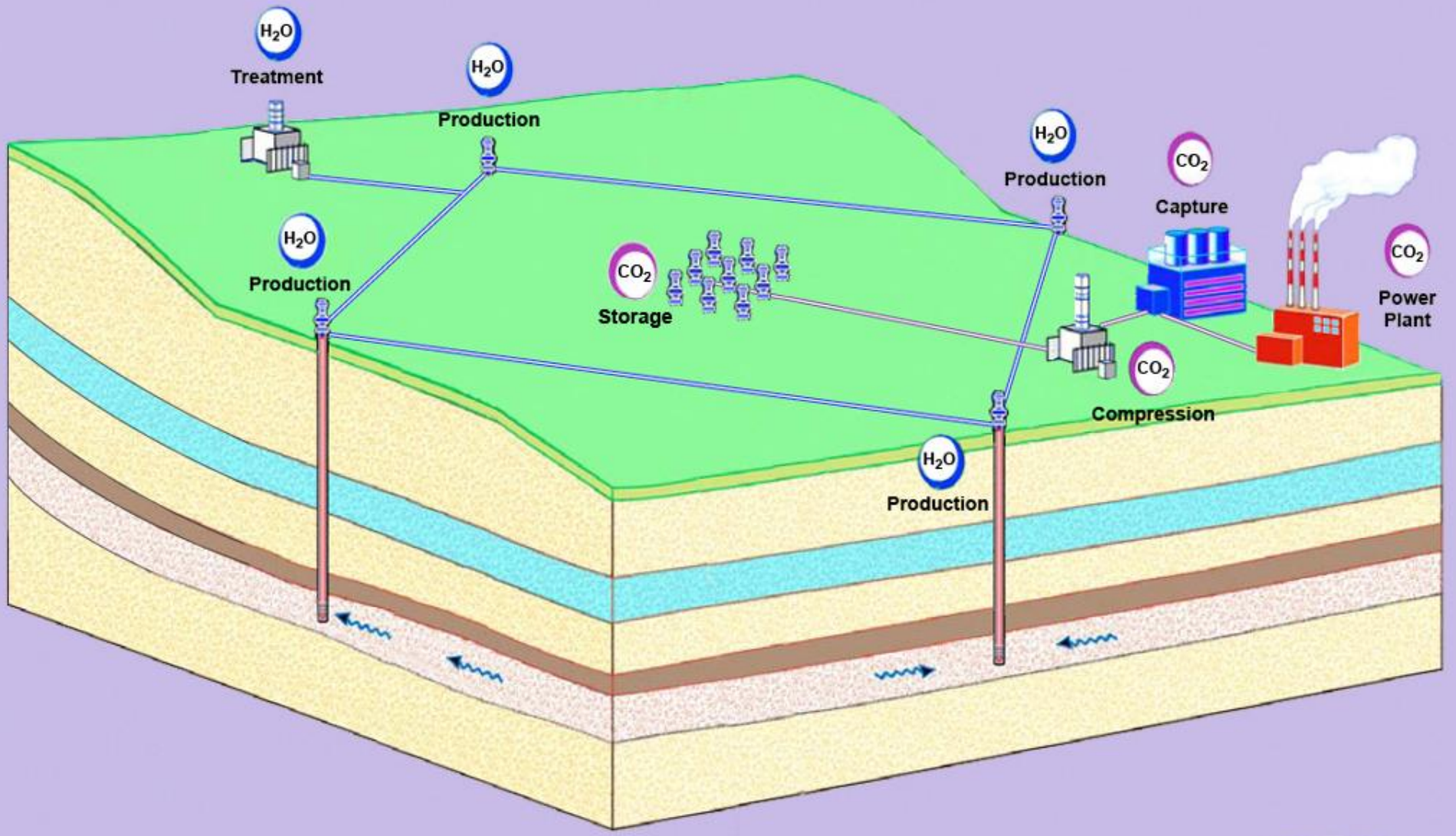
Injected CO_2 versus fluid leaving the domain



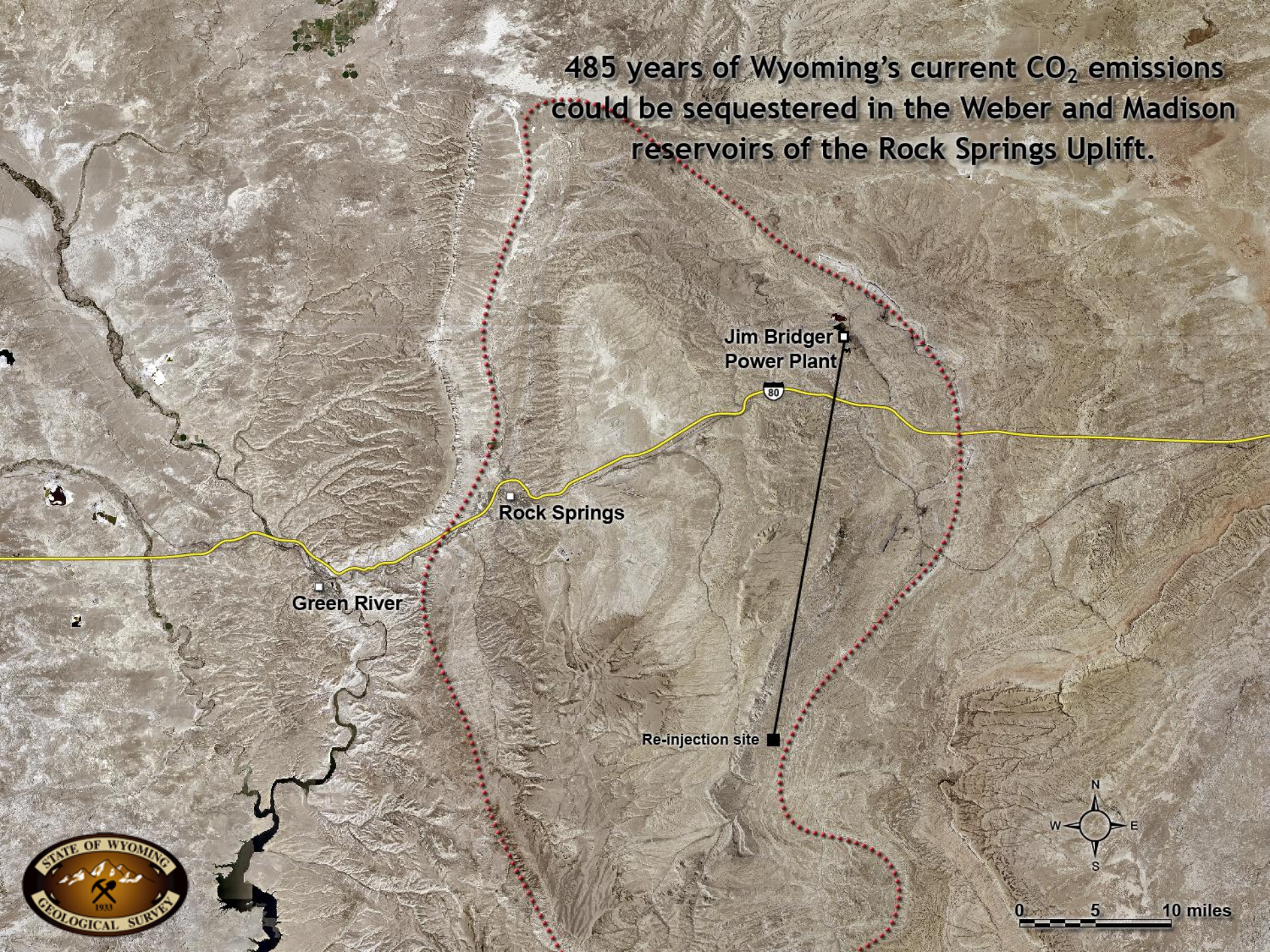
Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

Scale

- 750 Mt of CO_2 displaces ~1 cubic kilometer.
- 1 cubic kilometer of displaced fluids is ~6,000,000,000 barrels
- Salt Creek Oil production (the largest oil field in Wyoming) is ~680,000,000 barrels (120 yrs)
- 1 cubic kilometer of water is ~710,000 acre-feet.
- Boysen Reservoir is 792,000 acre-feet.

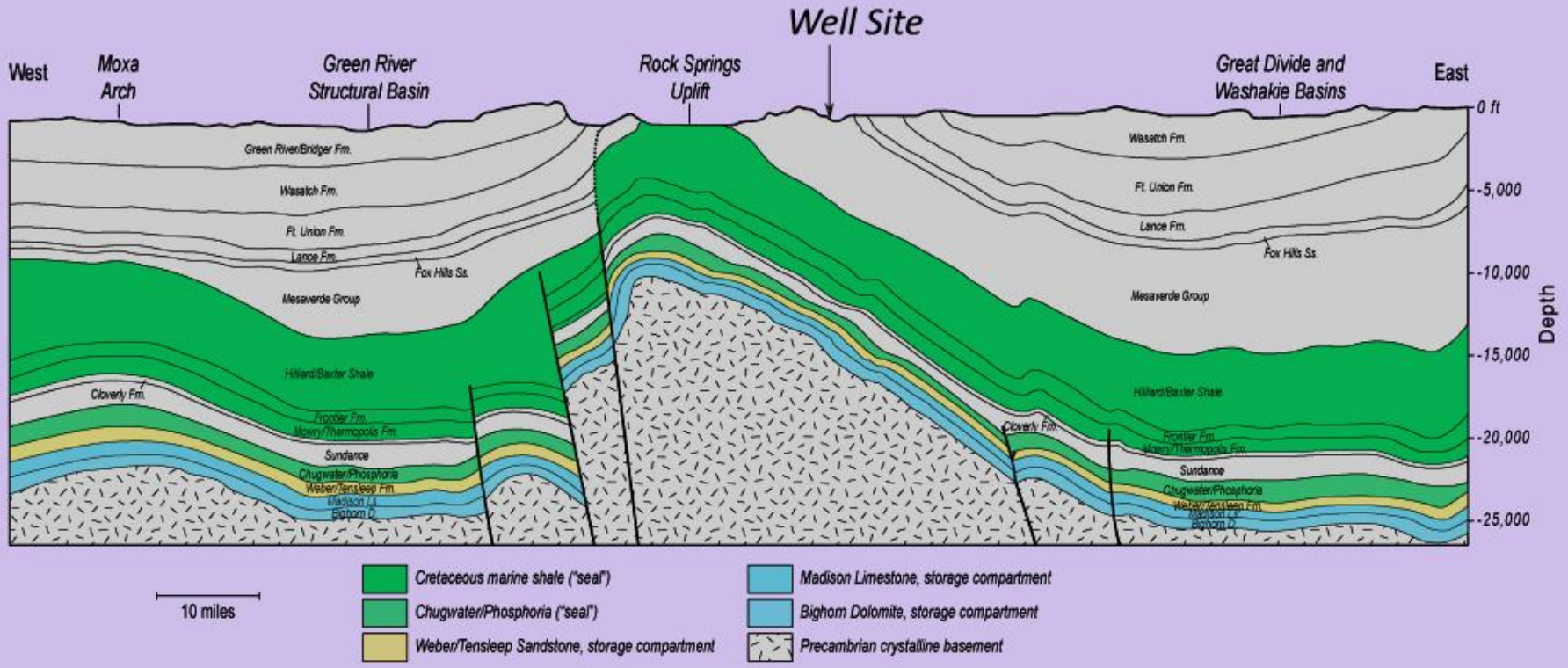


Modified from Surdam, R.C., Jiao, Z., Stauffer, P., & Miller, T., 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment: Wyoming State Geological Survey Challenges in Geologic Resource Development No. 8, 25 p.

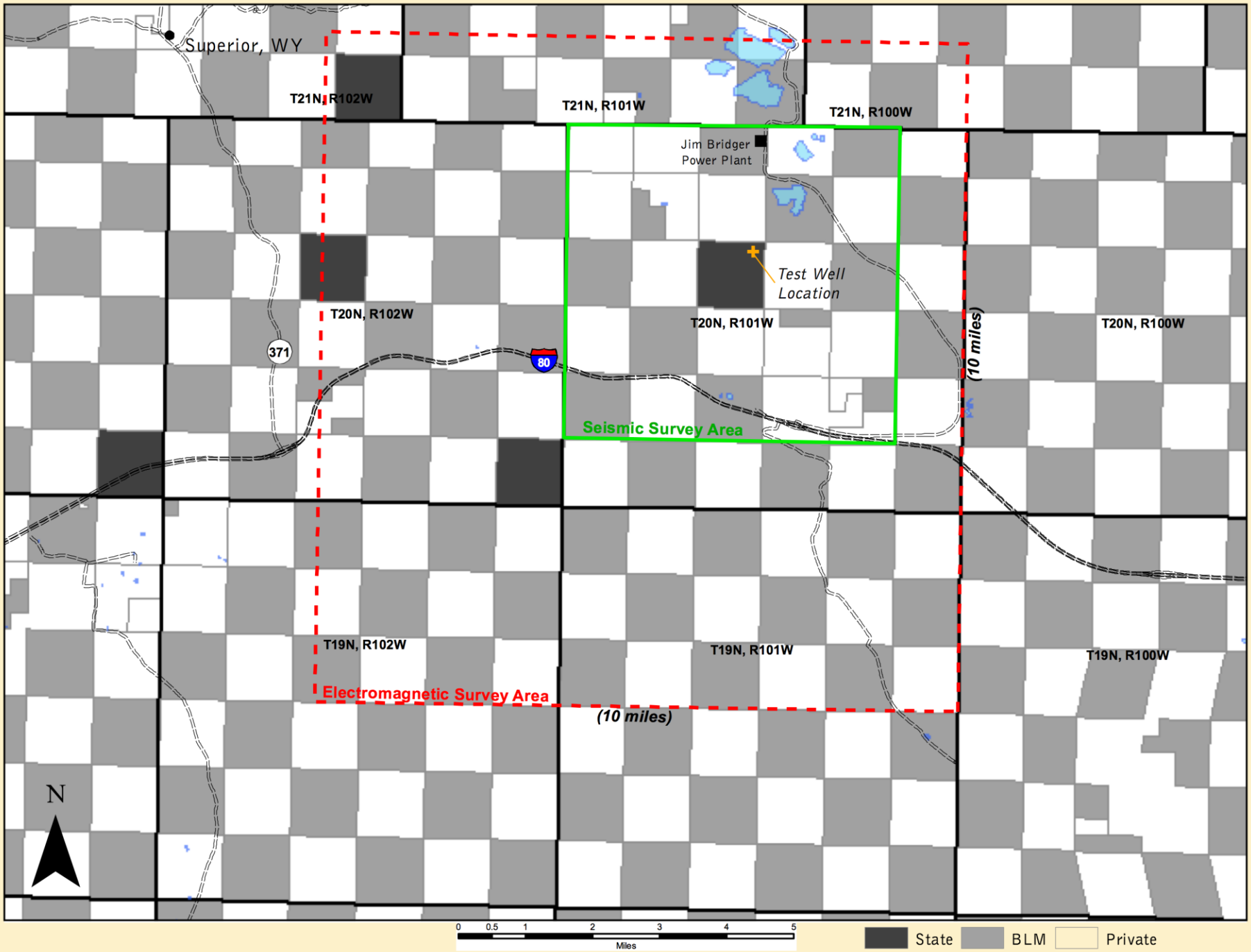

485 years of Wyoming's current CO_2 emissions could be sequestered in the Weber and Madison reservoirs of the Rock Springs Uplift.
Jim Bridger Power Plant
80
Rock Springs
Green River
Re-injection site
N
W
E
S
0
5
10 miles
STATE OF WYOMING
GEOLOGICAL SURVEY
1933

Conclusions

- **The most critical problem with commercial scale geological CO_2 sequestration is management of displaced fluids. To solve this problem, the Wyoming State Geological Survey proposes a strategy that includes integration of fluid production/water treatment with injection of CO_2.**
- **The greatest uncertainty in numerically simulating CO_2 sequestration processes is characterizing geological heterogeneity in 3 dimensions.**



STATE OF WYOMING
1933
GEOLOGICAL SURVEY


Superior, WY
T21N, R102W
T21N, R101W
T21N, R100W
Jim Bridger
Power Plant
Test Well
Location
T20N, R102W
T20N, R101W
T20N, R100W
371
80
(10 miles)
Seismic Survey Area
T19N, R102W
T19N, R101W
T19N, R100W
Electromagnetic Survey Area
(10 miles)
N
0 0.5 1 2 3 4 5
Miles
State
BLM
Private

Project Objective:
Design & Acquire 3-D/3-C Seismic Data & Other Geophysical Surveys

- Focus on Rock Springs Uplift and Moxa Arch
  - Well catalog and borehole risk assessment
  - Geophysical characterization
  - Structure and stratigraphic characterization
  - Experiments on mineralization and brine containment
- Data sharing on ExxonMobil Moxa Arch wells
- Baseline geophysical surveys of RSU

SER

University of Wyoming

State of Wyoming Geological Survey 1933

Project Objective:
Design & Complete Stratigraphic Test Well

- Drill stratigraphic test well on RSU with Baker Hughes, Inc.
- Obtain wirelogs, core, and cuttings from RSU to complement similar information from ExxonMobil deep acid gas injection well

Project Objective:
Design Commercial-Scale Sequestration Projects for Both Sites

- Complete detailed risk assessments
- Design commercial-scale sequestration projects for RSU & Moxa Arch sites based on interpretations of geophysical data, field and laboratory studies, measurements, and experiments on core and fluids
- Design includes displaced fluid management plan

SER

University of Wyoming

State of Wyoming Geological Survey 1933

WY-CUSP Philosophy & Goal

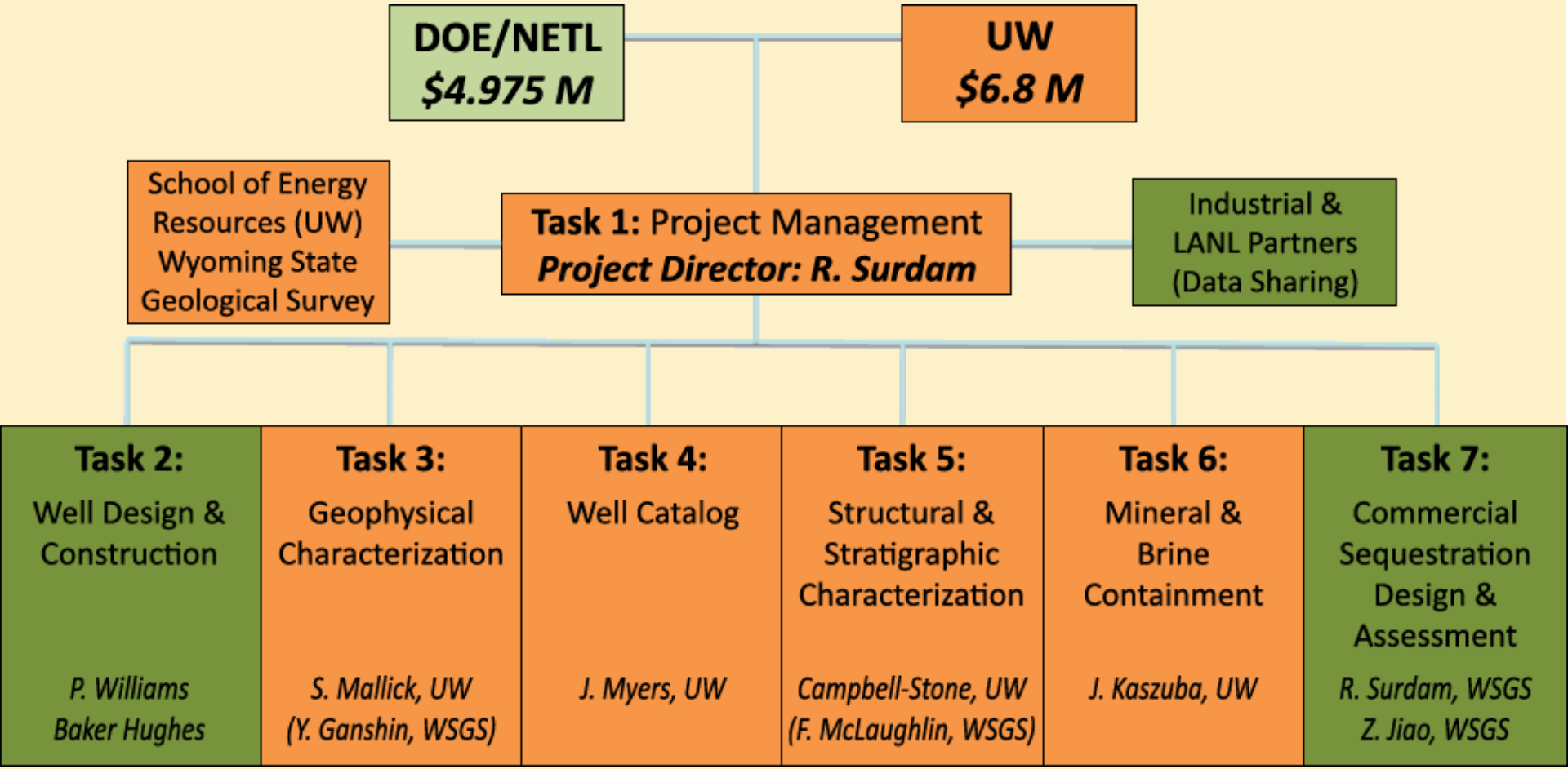
- Philosophy of WY-CUSP
  - Target closed geologic structures
  - Manage displaced water and put it to beneficial use
  - Build on current research by SER, WSGS, UW, and collaborators
- WY-CUSP Goal
  - Store commercial quantities of anthropogenic CO_2 safely and permanently in geologic formations in southwestern Wyoming

SER

UNIVERSITY OF WYOMING

STATE OF WYOMING GEOLOGICAL SURVEY 1933

Project Structure



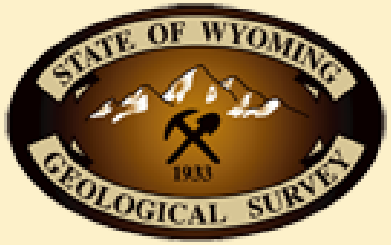
SER

UNIVERSITY OF WYOMING

STATE OF WYOMING 1933 GEOLOGICAL SURVEY

Project Structure:
Partners

University of Wyoming



Project Cost

	Year 1	Year 2	Year 3	Total Project Cost
Federal share	$4,975,000	$0	$0	$4,975,000
Non-federal share	$4,480,000	$1,830,000	$1,690,000	$8,000,000
Total	*$9,455,000*	*$1,830,000*	*$1,690,000*	*$12,975,000*

SER

UNIVERSITY OF WYOMING

STATE OF WYOMING GEOLOGICAL SURVEY 1933

Future Directions

Wyoming Governor Freudenthal's letter to the 60th (2010) Legislature:

"Other . . . recommendations in the University of Wyoming budget include $45 million for continuation and acceleration of carbon sequestration research . . ."

With this and other funds, UW hopes to develop a commercial-scale CO_2 sequestration site by 2016 that will be able to inject >>1 million tons of CO_2/year

SER

UNIVERSITY OF WYOMING

STATE OF WYOMING GEOLOGICAL SURVEY 1933